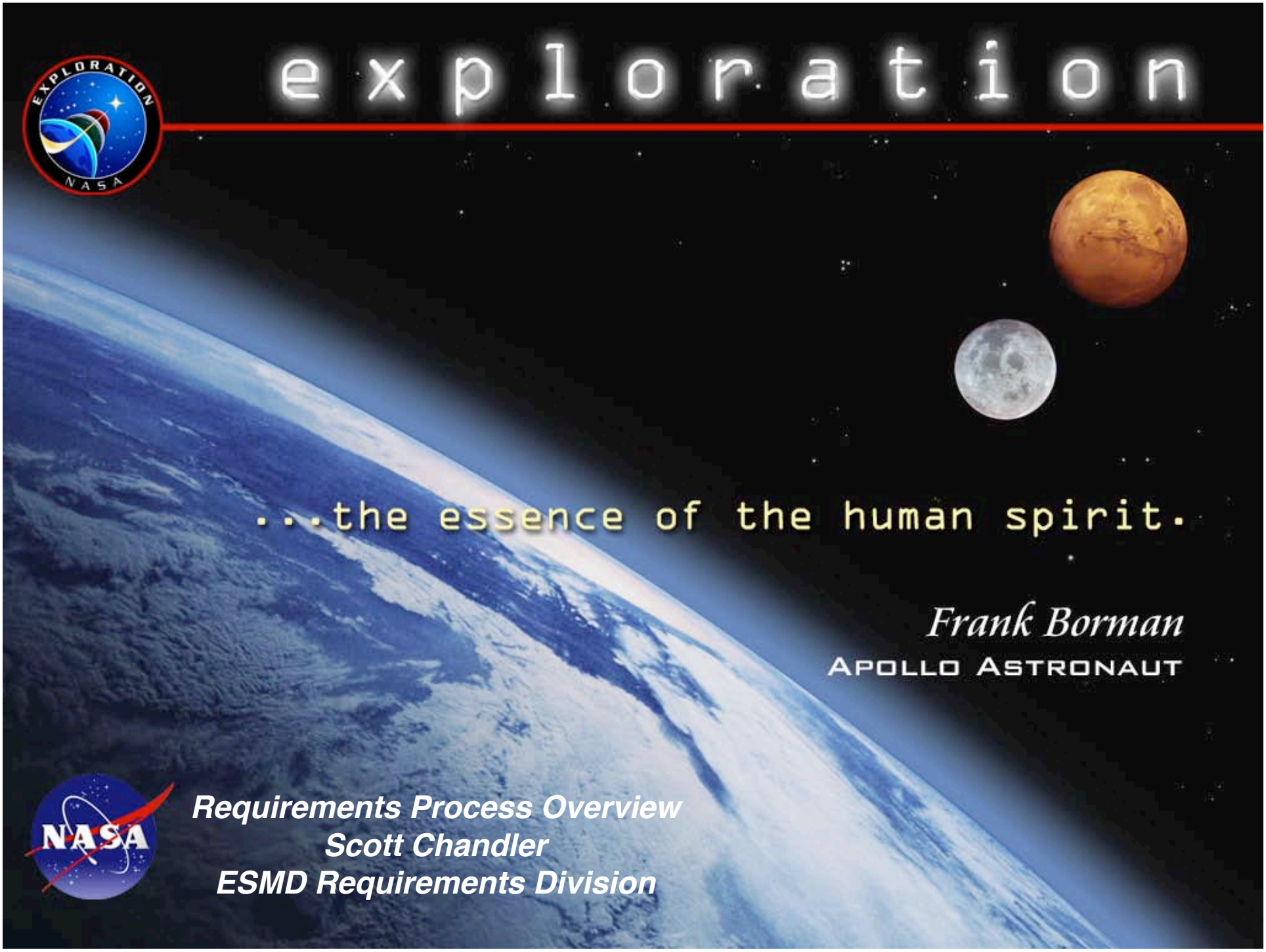


Requirements Process Overview
Scott Chandler
ESMD Requirements Division

The Vision for Space Exploration

The fundamental goal of this vision is to advance U.S. scientific, security and economic interest through a robust space exploration program

- ***Implement a sustained and affordable human and robotic program to explore the solar system and beyond***
- ***Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations***
- ***Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration***
- ***Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests***

Exploration Strategy Outline

- Re-establish competencies for crewed lunar and interplanetary flight spirals
  - *Ultimate architecture not known a priori*
  - *Stepping stone "spiral" approach to design and develop a "System-of-Systems"*
  - *Lunar testbed incrementally validates systems and operations concepts*
- Robotic precursors identify locations of interest and demonstrate technologies
- Extend capabilities and reduce dependence on logistics train
  - *Enable affordable and sustainable exploration of Mars*
  - *Open new commercial opportunities for products and services*

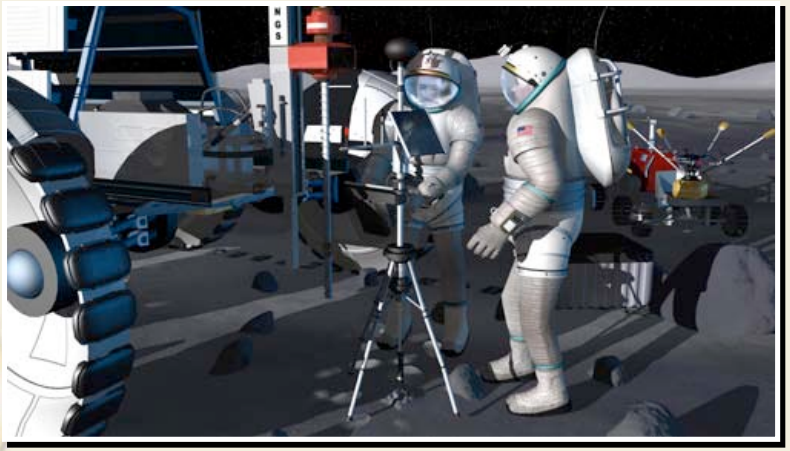
Exploration Systems Spiral Objectives

- Spiral 1 (2008-2014)
  - Provide precursor robotic exploration of the lunar environment
  - Deliver a lunar capable human transportation system for test and checkout in low Earth orbit
- Spiral 2 (2015-2020)
  - Execute extended duration human lunar exploration missions
  - Extend precursor robotic exploration of the Mars environment
- Spiral 3 (2020-TBD)
  - Execute a long-duration human lunar exploration campaign using the moon as a testbed to demonstrate systems (e.g., Lander, habitation, surface power) for future deployment at Mars
- Spiral 4 (~2025-TBD)
  - Execute human exploration missions to the vicinity of Mars
- Spiral 5 (~2030-TBD)
  - Execute initial human Mars surface exploration missions

Preparing for Mars Exploration

Our Moon as a test bed

–Technology advancement reduces mission costs and supports expanded human exploration



–Systems testing and technology test beds to develop reliability in harsh environments

–Expand mission and science surface operations experience and techniques

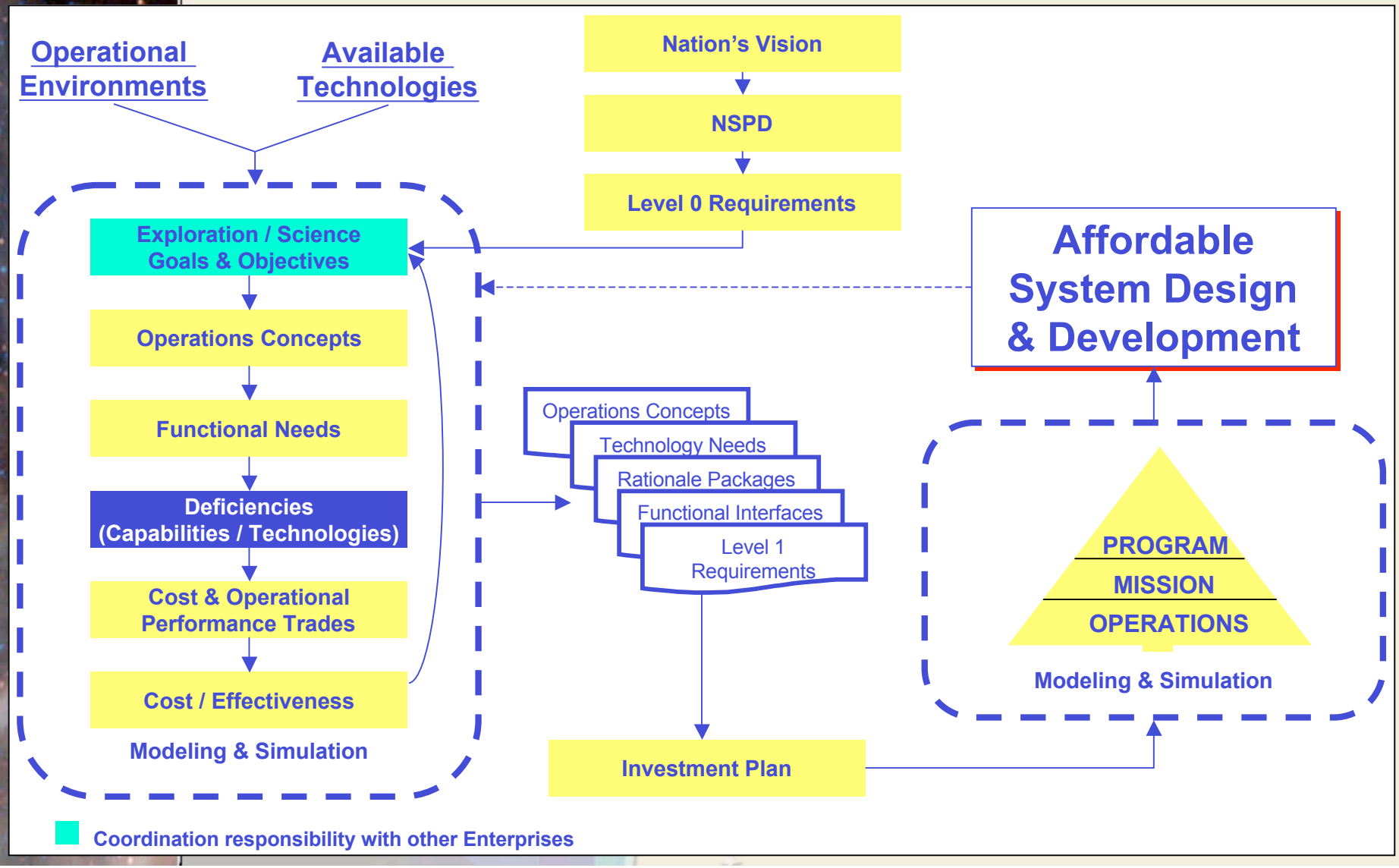
–Human and machine collaboration: Machines serve as an extension of human explorers, together achieving more than either can do alone

–Breaking the bonds of dependence on Earth: (e.g., life science/closed loop life support tests)

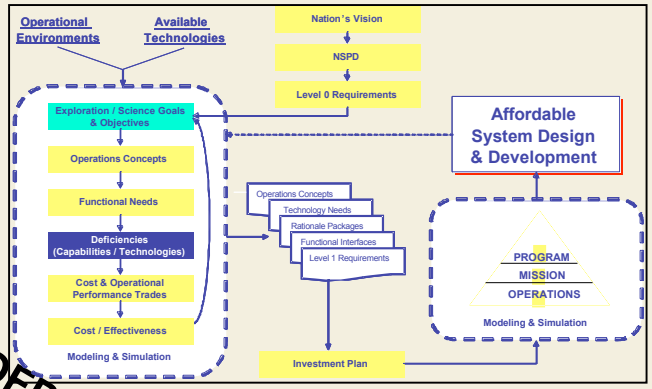
–Power generation and propulsion development and testing

–Common investments in hardware systems for Moon, Mars and other space objectives

Strategy-to-Task-to-Technology Process



Quality Functional Deployment (QFD) Flowdown



QFD

Architectural Campaigns

Strategic Objectives

Matrix A

Scores

Operational Tasks

Architectural Campaigns

Matrix B

Scores

Operational Attributes

Operational Tasks

Matrix C

Scores

Technologies

Operational Attributes

Matrix D

Scores

Affordability

Technologies

Matrix E

Scores

Supported by Cost, Operational & Performance Trades (SBA)

Requirements Development Flowdown

Broad Trades

Architectural Variants (Examples)

- Moon Short Stay
- Moon Long Stay
- Global Access
- Single Site
- Multiple Sites
- High-Earth Orbit
- Libration Points
- Mars Orbit
- Mars Short Stay
- Mars Long Stay

Technology Infusion (Examples)

- Chemical
- Nuclear
- Fuel Cells
- Solar
- ECLSS Closure
- Open Loop
- Storables
- Cryogenics
- Thermal Protection
- Breakthroughs

Operational Concepts (Examples)

- Pre-Deploy
- All-Up
- Lunar Orbit
- Libration Point
- Tandem
- Convoy
- Surface Stay
- Abort Options
- Staging Altitude
- Staging Strategy

Safety **Effectiveness** **Extensibility** **Affordability**

Focused Trades

Architectural Variants (Examples)

- Launch Constraints
- Return Strategy
- Staging Altitude
- Plane Change
- Tandem / Convoy
- Surface Strategy

Technologies & Sensitivities (Examples)

- Propellants
- Power
- Crew Size
- Surface stay
- Payload Down
- Payload Returned
- Launch Frequency
- Radiation Shielding

Mission Capture (Examples)

- Lunar Short Stay
- Lunar Long Stay
- Polar / Equatorial
- Global Access
- Libration
- Mars Staging
- Mars Return

OAG/STT Decision Panel

Concept of Operations and Draft Requirements

Preliminary Findings To Date

- Low-Lunar Orbit (polar) rendezvous superior staging location, as compared to Earth-Moon Libration (L1):
  - Can enable anytime return (via plane change) for lower total velocity
  - Lunar orbit variant reduces gross mass by ~20%
  - Provides better energy split between CEV and lander (smaller lander)
  - Shorter total mission duration and less crew exposure to deep space
- Low-Lunar Orbit rendezvous with anytime return capability can enable global access with limited surface stays
  - Long-duration polar or equatorial missions
  - Short-stay missions anywhere on the surface
- Earth Departure Stage (EDS) should be used to perform lunar orbit insertion
  - Unlike Apollo, launch capabilities will be most likely be constrained
  - Earth Departure Stage provides higher performance, resulting in lower total mass
  - Decouples CEV/EDS design thus simplifying CEV (return propulsive maneuver only)
- Electric propulsion can help reduce mass required to deliver cargo
  - Reduces gross total mass but increases dry mass
  - Not applicable for crew delivery (CEV), only applicable for cargo deployment

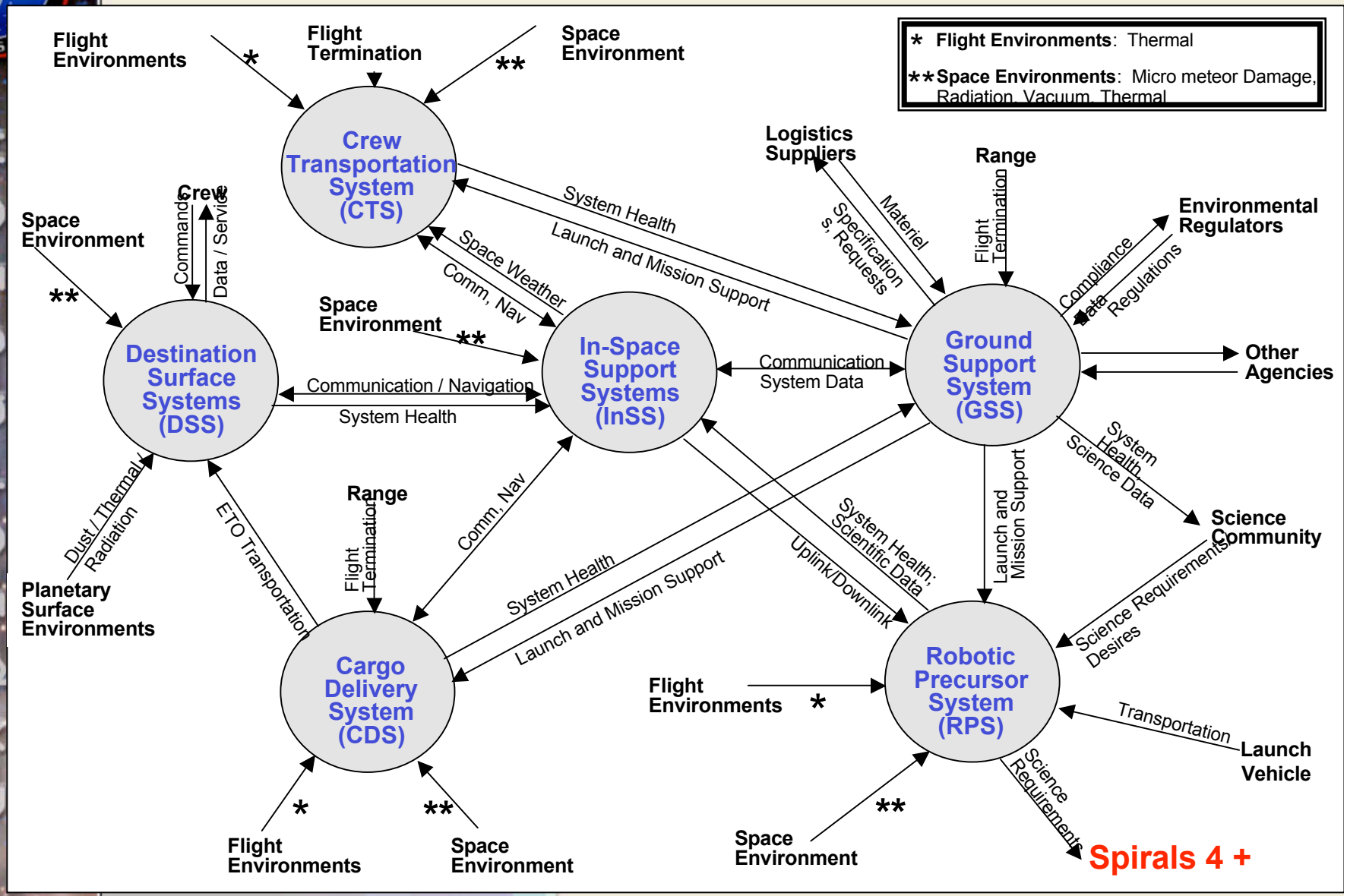
Preliminary Findings To Date

- Single crew module all the way to the lunar surface
  - Severe mass penalty (2 times higher)
  - Packaging and layout issues
  - Better metrics if CEV is in-space vehicle only
    - Earth-to-LEO transportation provided separately
    - Additional assessments in work
- Dual-pass aerocapture at Earth return may improve operational flexibility
  - Potential operational benefits (landing site phasing) for little mass penalty
  - Packaging and number of critical events detract from FOM evaluations (further assessments required)
- In-Situ Propellant Production may offer benefits for future spirals
  - Potential of reducing total mass, but requires significant infrastructure emplacement
  - Determination of technology availability, safety, infrastructure emplacement requirements, and economic affordability is necessary

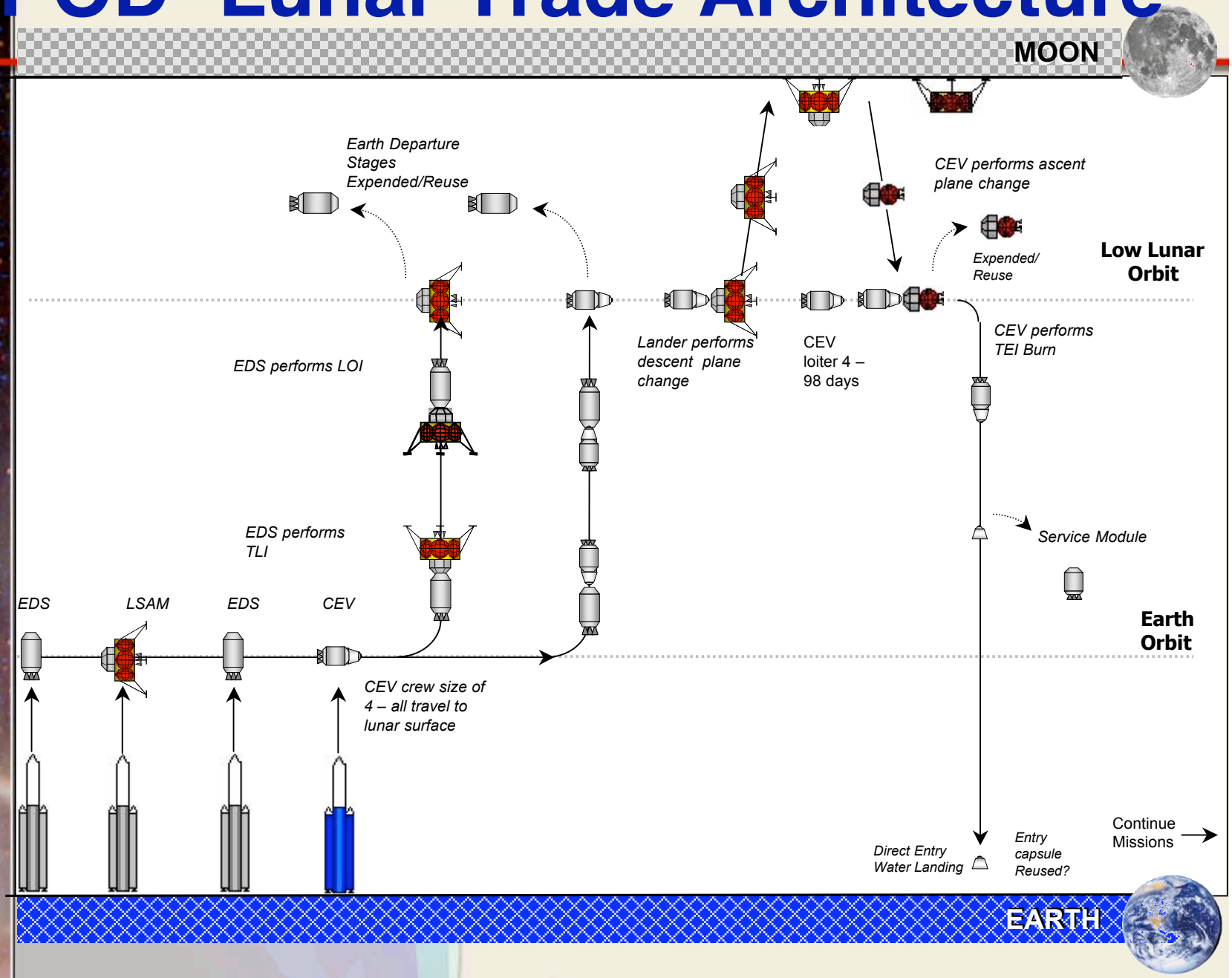
Architecture

- **Definition: Architecture?**
  - An architecture is an instantiation of a collection of required capabilities into a set of elements collectively known as a "system of systems"
  - Architectures which satisfy a "level 1" set of requirements can be defined by a common set of parameters
  - Architectures can also be defined in such a way that figures of merit of interest (eg., cost, schedule, reliability, technical performance) can be generated and compared in any arbitrary order
- **What is the purpose of a Point-Of-Departure architecture?**
  - The POD architecture was a means for RQ to establish the technical feasibility/validity of "level 1" (capability) requirements on a short schedule without penetrating to "level 2" (design)
  - It does not provide insight into the depth of the trade space afforded by the level 1 requirements so nothing can be said about its optimality as a design solution without further analysis

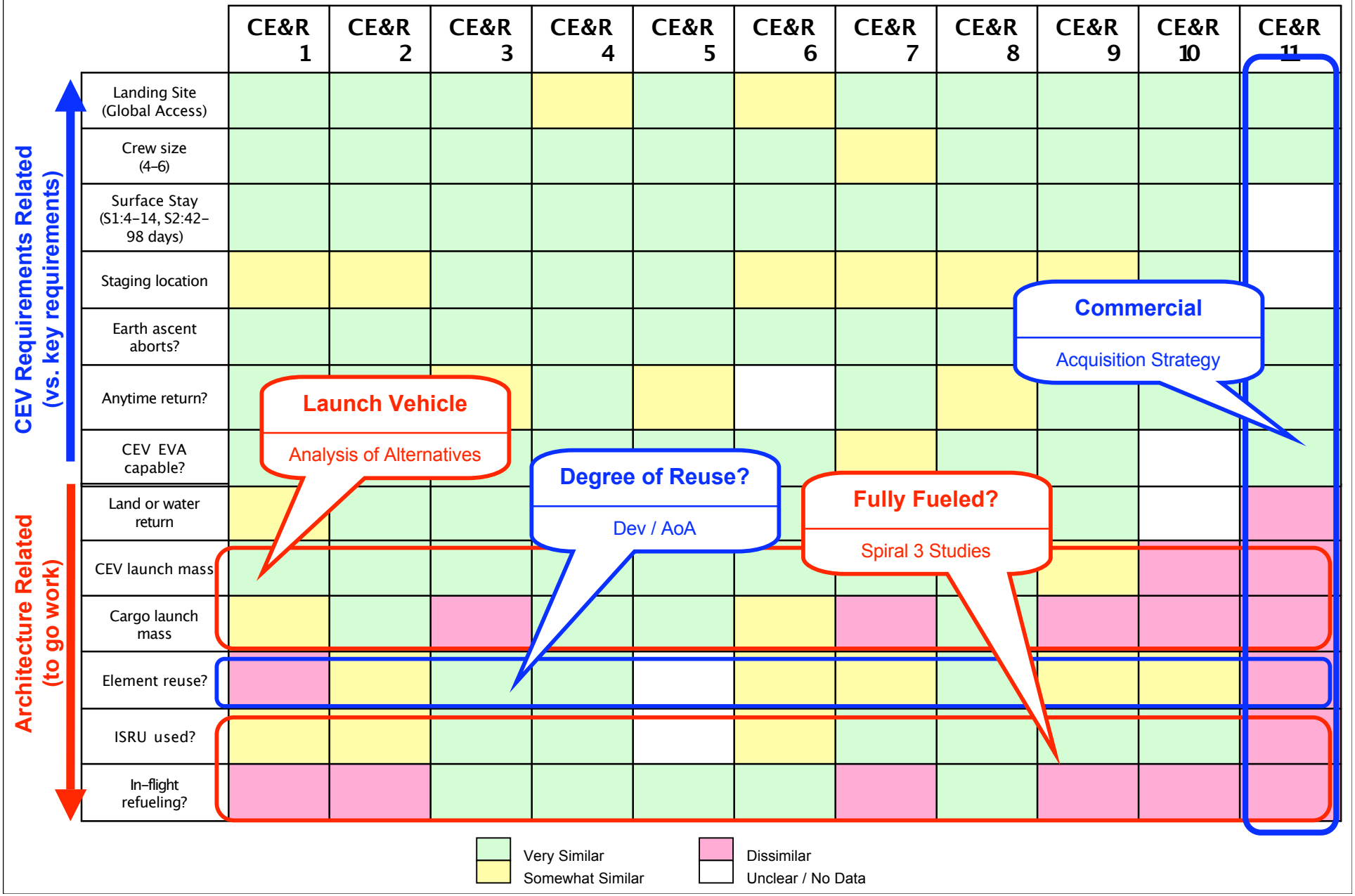
DRAFT Depiction of ESS (Spiral 3)



POD- Lunar Trade Architecture



CE&R contractor mid-term summary



Cross-Agency Integration of Technology for Exploration

Transit & Launch Systems for Crew Transport & Support

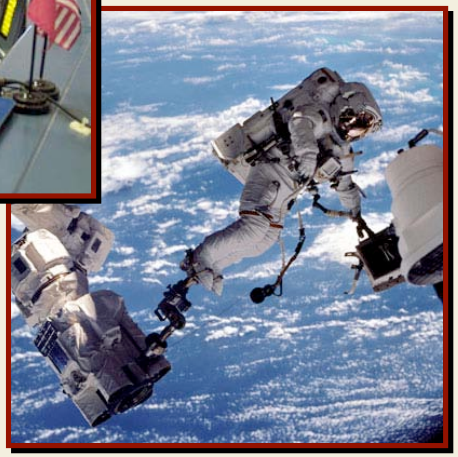
Human Spaceflight

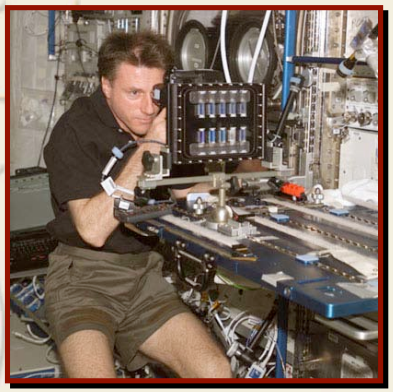
Surface & Orbital Systems

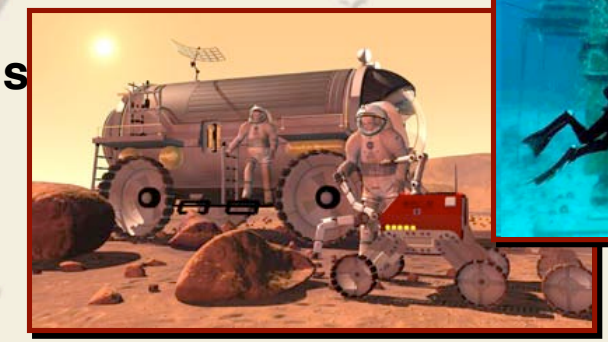
Supporting Basic & Applied Research

Technology Development for Long Duration Habitation

Preparing for Future Missions Moon, Mars, & Beyond







The Human Body in Space

Surviving the Odyssey

Harmful Radiation Effects

- ***Tissue Degeneration***
- ***Carcinogen Exposure***

Physiological Changes

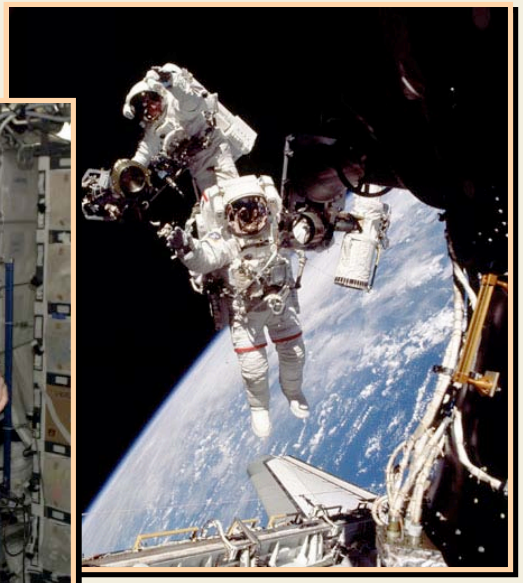
- ***Cardiac arrhythmia***
- ***Osteoporosis***

Acute Medical Problems

- ***Toxicity***
- ***Ambulatory Health Problems***

Behavioral Problems

- ***Disorientation***
- ***Sleep Problems***



One Step at a Time

Affordable, Sustainable, Focused, Achievable